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Methyl-Violet as a Red-Sensitiser of the Photographic Plate.

By

Usaburo Yoshida.

(Received Oct. 22, 1917.)

Nearly one year ago, when the writer was developing, under the illumination of a red light, a photographic plate which had been accidentally stained by a trace of methyl-violet, the plate was found to be fogged at the neighbourhood of the stained portion of the plate. As the same phenomenon did not occur when the process was carried on in the darkness, the question naturally arose whether this fogging might be due to a red-sensitising action of the methyl-violet. In the present experiment this was tested and the result came out positive.

50 ccs of ethyl alcohol were mixed with the same volume of water, and 5 ccs of ammonia were added. This solution was cooled by melting ice. Next 1 gr. of methyl-violet was dissolved in 1000 ccs of cold absolute alcohol, and 5 ccs of this were added to the former. The solution thus prepared was well stirred, and cooled by melting ice. The best result was obtained with this solution so far as the writer has tried. The photographic plate to be sensitised was soaked in this solution for 5 minutes or more, and then was rinsed in alcohol and dried. This sensiting process was carried on, of course, in the darkness.

For the sensitising methyl-violet, Grübler's 5B was used throughout the present experiment, but Grübler's 6B and the methyl-violet made by Merck may be used equally well.

For testing the plate, the spectrum emitted by a Nernst lamp was photographed with the aid of a small quartz spectrograph, for

the sake of convenience, though quartz is not needed for the present purpose.

The photographs represented in Fig. 1 were taken with Seed's dry plate 27. The time of exposure was varied, step by step, from 24 second to a few tenths of a second. From 24 sec. to 3 sec. each duration of the exposure was reduced by 3 sec. from that of the preceding longer one; and then followed 1 sec. exposure, and then a momentaneous one. Corresponding to each step of the exposure, the position of the photographic plate was displaced a little in the direction perpendicular to the spectral band, so that a system of the spectra as shown in the annexed photographs was obtained. For the comparison spectrum, the writer employed a cadmium spark. The photographs indicated by Fig. 1, 2, 3 and 4 were obtained in the same experimental condition, and were developed in the same bath of a metol developer with an equal time of development.

Fig. 2 was obtained with a Seed's dry plate 27, sensitised in the manner described above; Fig. 3 with an orthochrome plate, non-filter, of Lion; and Fig. 4 with the same orthochrome plate sensitised by the methyl-violet.

Curves 1, 2, 3 and 4 represent curves of equal density, each one corresponding to the same numbered figure.

In Eder's Handbuch der Photographie[1] it is stated that methyl-violet sensitises silver bromide strongly for the yellow region in the neighbourhood of the D line. But as is clearly seen from the curves 2 and 4, the portion of the spectrum to which the plate was most strongly sensitised is in the neighbourhood of 640 $\mu\mu$. Thus the photographic plate was rendered sensitive to the light of the shorter wave-lengths in the red.

With regard to the sensitiveness to the red light both in the intensity and the limit of the wave-length the plate thus sensitised is never superior to the panchromatic plate of Wratten and Wainwright; it was, however, ascertained that the plate thus sensitised was more sensitive to the light of shorter wave-lengths than the latter.

When the orthochrome plate mentioned above was sensitised by the methyl-violet, a new maximum of sensitiveness at 640 $\mu\mu$ was found in addition to the original maximum at 560–570 $\mu\mu$; and the spectrum region to which the plate was made sensitive extended to about 650 $\mu\mu$,

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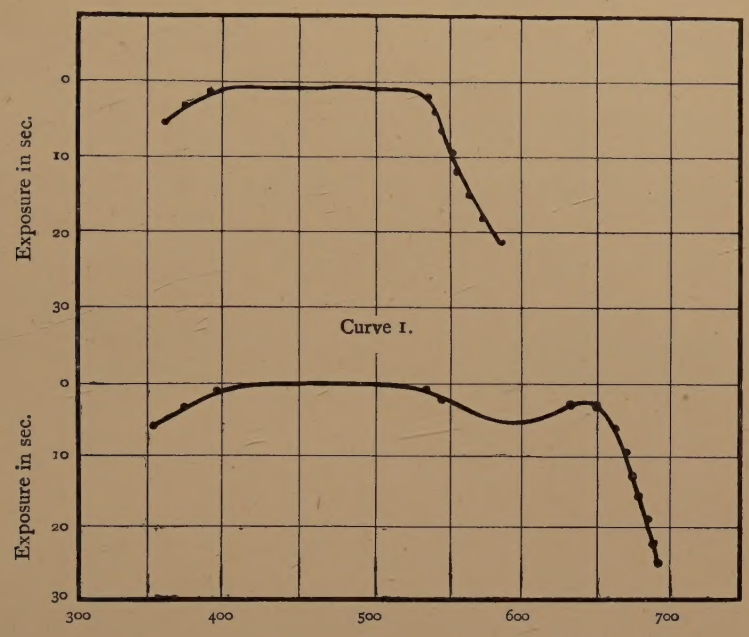
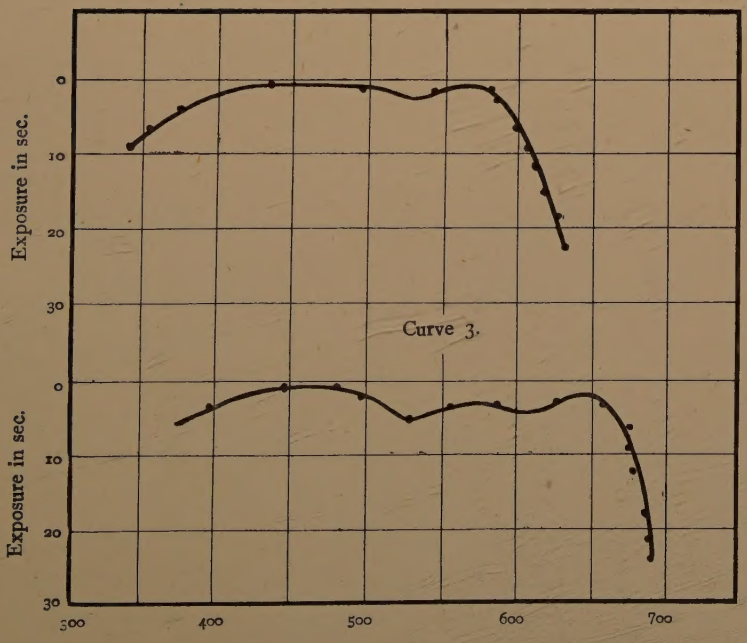
1 Eder; Ausführliches Handbuch der photographie, II 3, p. 466.

as shown in Fig. 4 and Curve 4. Though the sensitiveness of the plate thus sensitised to the red was a little reduced at the green and yellow region, it could be used as a rapid plate sensitive to the light of nearly all wave-lengths except those of extreme red.

In conclusion, the writer's sincere thanks are due to Profs. T. Mizuno and M. Kimura for their interest in the work.



Curve 2.



Curve 4.

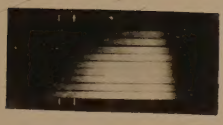


Fig. 1.

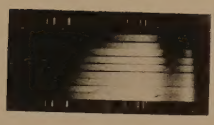


Fig. 2.

Fig. 3.

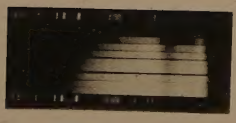


Fig. 4.

The Reversal of Spectrum Lines produced by a Spark under Water.

By

Toshikazu Mashimo.

(Received Oct. 22, 1917.)

From the researches of P. Konen[1], H. Konen[2], Sir N. Lockyer[3], G. H. Hale[4] and H. Finger[5], it has been generally established that many lines are reversed in the spectrum of a spark under water. Moreover G. H. Hale found that the number of reversed lines increased in the more refrangible region. It may be remarked here that in all these researches the region examined extended only down to λ 2000 Å.U., so that data for the extreme ultra-violet region are entirely lacking.

In 1913, V. Henri[6] reported that, if we employ an aluminium spark of high frequency under water as the source of light, a continuous spectrum extending to λ 2150 Å.U. could be obtained with a fairly strong intensity.

On experimenting with Henri's method, using several different metals as electrodes, the writer found that the metallic lines due to the electrode appeared mingled with the continuous spectrum; and further, that some of those lines were always reversed while others remained unreversed, so that Henri's method affords us a convenient

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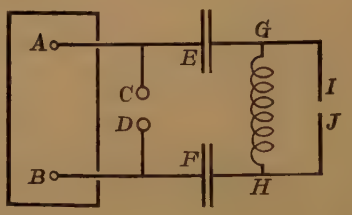
1 P. Konen, Phys. ZS., **3**, 537 (1901–1902).
2 H. Konen, Ann. d. Phys., **9**, 742 (1902).
3 Sir N. Lockyer, Proc. Roy. Soc., **70**, 31 (1902).
4 G. E. Hale, Astrophys. Jour., **15** 132 (1602), **17**, 154 (1903). Publications of the Yerkes Observ., Vol. 3, Part 2, p. 29.
5 H. Finger, Ber. d. deutsch. phys. Gesell., **4**, 369 (1909). ZS. f. wiss. Photogr., **7**, 329 (1909).
6 V. Henri, Phys. ZS., **14**, 516 (1913).

means for studying the behaviour of different lines in the spectrum of a spark under water.

Although the phenomenon is very complicate and depends greatly upon the mode of excitation of the spectrum, still it may serve as a means whereby to examine the difference in the conditions under which different lines are excited.

The arrangement for producing the Henri spark is shown in Fig. 1. The terminals A, B of a 70 cm induction coil were joined to the spark gap at C, D and to the inside coatings of two leyden jars E, F. The outside coatings of these jars were joined to the aluminium rods I, J, which were immersed to a depth of 2 or 3 cm. in distilled water. A coil of small self-induction G, H, was inserted in parallel with the spark gap I, J which served as the source of light.

Fig. 1.



The light from the spark under water passed directly to the slit of a quartz spectrograph of size A made by Hilger. The collimator of the spectrograph was held in a vertical position. A Schumann photographic plate prepared by Hilger was employed. It may be remarked here that the photographic reversal was carefully eliminated from that of the true reversal of the line.

In the present experiment, the metals used for electrodes of a spark under water were *Al*, *Zn*, *Cd* and the amalgum of zinc.

In the following, detailed accounts are given for each of these metals.

(1) *Aluminium.*

Among the metal spectra, that of aluminium extends far more to the extreme ultra-violet region than those of other metals.

For this metal, Finger found certain relations between the term number and the type of lines.

In the following table, we notice that the non-series lines appear always as the emission lines. On examining the photograph, the writer also noticed that the lines belonging to the first subordinate series were more easily reversed than those belonging to second subordinate one.

It may be worthy of mention that of the six lines lying in the most refrangible part, the type of lines 1930 and 1935 are different from the remaining four lines.

TABLE I.

ALUMINIUM.

Term number	λ in Å.U.	Intensity (Condensed (spark in air)	Result obtained by using Henri's method		Finger's result
			Type of line. "e" signifies emission "a" signifies absorption	Intensity	
	1854	5	e	1	
	1857	4	e	1	
	1862	6	e	2	
	1930	5	a	3	
	1935	7	a	3	
	1990	8	e	4	
I. N. II, 8	2205	2	a	1	
I. N. I, 8	2210	2	a	1	
I. N. II, 7	2263	3	a	2	
I. N. I, 7	2268	3	a	2	
I. N. II, 6	2367	6	a	3	
I. N. I, 6	2378	6	a	3	
I. N. II, 5	2567	3	a	2	a
I. N. I, 5	2575	3	a	2	a
	2632	4	e	2	e
II. N. II, 4	2653	3	a	2	a
II. N. I, 4	2661	3	a	2	a
N.	2816	5	e	4	
	3057	3	e	3	
	3065	2	e	2	
I. N. II, 4	3082	5	a	3	a
I. N. I, 4	3093	5	a	3	a
	3587	5	e	4	
II. N. II, 3	3944	5	a	2	a

(2) *Zinc.*

The non-reversal of 3076 Å.U. is noticeable. McLennan investigated the absorption spectra of zinc vapour at this region. In his first experiment[1] he found no absorption line at λ 3076 contrary to his expectation that he would obtain a pair of absorption lines at λ 2139

1 McLennan, Phil. Mag. **28**, 361 (1914).

TABLE 2.

ZINC.

Term number	λ in Å.U.	Intensity (Condensed spark in air)	Result obtained by using Henri's method		Finger's result
			Type of Line. "e" signifies emission "a" signifies absorption	Intensity	
P. 2	2026	3	a	2	
P. 2	2062	3	a	2	
	2064	3	e	2	
	2087	2	a	1	
	2097	3	a	1	
	2100	3	e	2	
	2102	3	a	1	
	2105	2	a	1	
II. n.	2139	5	a	2	
	2265	3	e	2	
	2288	2	a	1	
II. N. I, 7	2487	2	e	1	
	2491	2	e	1	
P. 1	2502	5	e	4	
II N. III, 5	2557	6	e	5	
I. N. II, 5	2771	2	e	2	
I. N. I, 5	2801	3	e	2	
	2832	1	a?	1	
	3076	2	e	1	
I. N. III, 4	3282	4	e	2	e
I. N. II, 4	3303	5	e	2	a
I. N. I, 4	3345	5	e	2	a

and 3076 Å,U. But in his second experiment[1], he observed that, in the absorption spectrum of non-luminous zinc vapour, there is a strong symmetrically spaced absorption band at λ 2139·3 Å.U. and a very narrow sharply defined one at $\lambda = 3075{\cdot}99$ Å.U. In the present experiment, the line λ 2139 appeared as a reversed line.

(3) *Cadmium.*

Lines λ 2288 and 3261 Å.U. which appeared as absorption lines

[1] McLennan & Edwards, Phil. Mag., **30**, 695 (1915).

in the experiment of R. W. Wood and D. V. Guthrie[1], and later, confirmed by McLennan and Edwards[2], were also found as reversed lines in the present experiment.

TABLE 3.

CADMIUM.

Term number	λ in Å.U.	Intensity (Condensed spark in air)	Result obtained by using Henri's method		Finger's result
			Type of Line. "e" signifies emission "a" signifies absorption	Intensity	
	2144	7	a	4	
	2195	5	e	4	
	2240	3	e	2	
	2265	6	e	3	
	2288	4	a	2	
	2313	4	e	4	
	2321	3	e	2	
	2329	2	e	1	
	2470	1	e	1	
	2573	4	e	5	
	2749	4	e	5	
I. N. I, 5	2981	3	e	1	
	2987	1	e	1	
	3069	2	a	1	
	3089	2	e	1	
	3095	2	a?	1	
II. N. II, 4	3133	2	e	1	
II. N. I, 4	3253	3	e	2	
N	3261	2	a	2	
I. N. III, 4	3404	4	e	2	
I. N. II, 4	3468	4	e easily reversible	2	a
I. N. I, 4	3613	5	e easily reversible	2	a
Cd 7	4416	1	e	1	a

1 R. W. Wood & D. V. Guthrie, Astrophys. Jour., **29**, 211 (1901).
2 McLennan & Edwards, Phil. Mag., **30**, 695 (1915).

TABLE 4.

MERCURY.

Term number	λ in Å.U.	Intensity (Condensed spark in air)	Result obtained by using Henri's method		Finger's result
			Type of Line. "e" signifies emission "a" signifies absorption	Intensity	
	2052	2	e	1	
	2225	4	e	2	
	2260	3	e	2	
	2264	2	e	2	
I. N. III, 6	2378	2	e	1	
	2398	1	e?	1	
I. N. II, 6	2482	1	a	1	
I. N. III, 5	2537	3	a	3	
	2603	1	e	1	
	2605	1	e	1	
	2848	4	e	2	
I. N. III, 4	2967	4	e	3	
I. N. II, 3	3132	3	e	3	
	3145	3	e	3	
I. N. I, 4	3655	4	e	3	
II. N. III, 3	4047	2	e	2	
	4078	2	e	2	
	4340	4	e	3	
II. N. II, 3	4359	4	e	3	

(4) *Mercury.*

To obtain the spark spectrum of mercury under water, zinc amalgum was employed as the electrode, lines belonging to zinc being excluded afterwards.

Among the mercury lines, 2537 appeared always reversed as had already been observed by Wood and several other investigators.

It is interesting to note that in several instances the appearance of the spectrum lines of various metals, obtained when using the metal itself as the electrode of Henri's spark under water, resembled in some respects the absorption spectra of non-luminous metallic vapours as observed by McLennan and Edwards.

Comparing the writer's data with those of Konen and Finger, it will be seen that the latter examined the lines in the region between λ 2000 and 4700 Å.U., while the former extended his examination down to λ 1850 Å.U., and, in agreement with Hale, found that reversed lines increase as we advance in the more refrangible region. As regards the relationship between the reversal and the term number of lines in the spectral series, which was discussed by Finger, the present experiment does not give sufficient data for an opinion.

As mentioned above, V. Henri recommended the use of the high frequency spark spectrum of aluminium under water as a convenient source for giving a continuous spectrum in the ultra-violet region down to 2150 Å.U. Recently E. P. Lewis[1] has shown that the Geissler tube discharge of hydrogen gives a continuous spectrum extending to a still more refrangible part.

In the present experiment, the statement of Lewis was found to be quite true; and the writer believes that probably the Geissler tube discharge of hydrogen may be recommended as one of the most convenient sources for obtaining a continuous back ground in the absorption experiment at the extreme ultra-violet region.

The writer's cordial thanks are due to Prof. Mizuno and Assist. Prof. Takamine for their kind advice.

1 E. P. Lewis, Science, **41**, 977 (1916).

The Effect of an Electric Field on the Spectrum Lines of Helium.

Part II.

By

Toshio Takamine and Noboru Kokubu.

(Received Nov. 3, 1917.)

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§ 1.

Adopting the method first employed by Lo Surdo[1], one of the present writers, in conjunction with Mr. Yoshida[2], examined the effect of an electric field on the spectrum lines of helium.

The present paper describes the results obtained by further investigations relating mainly to the more refrangible lines of helium.

The arrangement was essentially the same as in the former experiment except that a valve tube and a spark gap were inserted in series with the discharge tube in the secondary circuit of an induction coil. For the capillary portion of the discharge tube, a transparent fused silica tube was employed. Helium gas prepared by Hilger was used in the present experiment. Beside the 4 prism spectrograph mentioned in the former paper[3], a 2 prism spectrograph was constructed; for the ultra-violet part, a quartz spectrograph (size C) of Hilger was employed. An Wollaston prism of quartz, and two quartz-fluorite achromatic lenses made by Hilger, were used for projecting the image of the source on the slit of the quartz spectrograph.

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1 Lo Surdo, Rendiconti d. Lincei, **22**, 664 (1913).

2 T. Takamine and U. Yoshida, Mem. Coll. of Sci., Kyoto **2**, 325 (1917).

3 T. Takamine and U. Yoshida, Mem. Coll. of Sci., Kyoto, **2**, 137 (1917).

The dispersion of these spectrographs were as follows :—

4 prism spectrograph ..... 19 Å.U. per mm. at H_γ,
2 „ „ ..... 27 Å.U. per mm. at H_δ,
Quartz spectrograph ..... 16 Å.U. per mm. at $\lambda = 3000$ Å.U.,
9 Å.U. per mm. at $\lambda = 2500$ Å.U.

§ 2.

Some of the photographs obtained in the present experiment are reproduced in Pl. III and IV. As in the former paper, notations p- and s-component are uesd to represent the parallel and perpendicular component respectively.

In the region examined, between λ 5200—2200 Å.U., 11 affected helium lines, in addition to the 9 lines reported in the former paper, were observed.

The following table contains the wave-length, series relation and the dispersion on our photographs for each line.

TABLE I.

λ in Å.U.	Series	Dispersion in Å.U. per mm.
4388	Parhelium I. N. 5	21·0 (4 Prism Spectrograph)
4169	„ II. N. 6	29·5 (2 Prism Spectrograph)
4144	„ I. N. 6	29·0 („)
4026	Helium I. N. 5	8·5 (4 Prism Spectrograph) 24·5 (2 „ „)
4009	Parhelium I. N. 7	24·0 (2 Prism Spectrograph)
3965	„ H. 4	21·5 („)
3868	Helium II. N. 6	18·0 („)
3830	Combination series, m=6.	16·5 („)
3820	Helium I. N. 6	16·0 („)
3614	Parhelium H. 5	27·6 (Quartz Spectrograph)
3448	„ H. 6	25·0 („)
2945	Helium H. 5	15·2 („)

Of the 11 lines above mentioned, Stark and Kirschbaum[1] examined 4169, 4144, 4026, 3965, 3820 and 3614. Later, the fine separation of the line 4026 was observed by Koch[2].

[1] Stark and Kirschbaum, Ann. d. Phys., **43**, 1017 (1914).
[2] The results obtained by Koch are noted in the monograph of Stark: „Electrische Spectralanalyse chemischer Atome" S. Hirzel, (1914), pp. 73, 74.

Employing Lo Surdo's method, Brunetti[1] examined the lines 4144 and 4026, but no quantitative measurement seems to have been carried out.

In 1915, Koch[2] found that in strong fields a series of new lines appeared in the helium spectrum, whose frequencies could be expressed by a formula of the Ritz type :—

$$\nu = (2, p, \pi) - (m, p, \pi),$$

where

$$m = 3, 4, 5 \ldots\ldots,$$

and p, π are the series constants for the principal series. According to Koch, the calculated and the observed wave-lengths are as follows :

$\lambda_{calc.}$ in Å.U.	6068.85	4518.65	4046.30	3830.05
$\lambda_{obs.}$,,	6060	4518.77	4046.02	— .

Now, in some of our photographs, the line λ 3830, whose existence was predicted but not observed by Koch, made its appearance; showing the same peculiarities as noted by Koch for other lines.

Here it must be mentioned that, as the spectrum we obtained is by no means pure, we cannot be sure of the origin of any new lines unless they present some peculiar features in the electric field.

In the case of the above cited line λ 3830, the displacements of the p- and s-components toward the red side, as well as the sudden increase of their intensities in strong electric field, showed at once that they are of the same type of lines as described by Koch.

In the course of measuring the photograms, we noticed that the two lines lying at λ 2804 and λ 2482 were displaced slightly toward the red side in the field $E = 60000$ volt/cm. Although there remains some doubt as to the origin of these two lines, they seem to be the mercury lines 2804.4 (I. N. I. 6) and 2482.1 (I. N. II. 6).

§ 3.

To determine the intensity of the electric field, Stark's data for H_γ line were relied on, as in the case of former experiments.

In the following we give detailed accounts for each of the lines mentioned above.

Figs. 1, 2, 3, 4 and 5 (Pl. I) illustrate the mode of separation of

1 Brunetti, Rendiconti. d. Lincei, **24**. (1), 719 (1915); **24**, (2), 55 (1915).

2 Koch, Ann. d. Phys., **48**, 98 (1915).

the lines λ4144, 4026, 4009, 3820 and 4388 respectively, The results obtained by Stark are marked by asterisks on Figs. 2, 4 and 5.

(1) λ : 4144. (Pl. I, Fig. 1)

The amounts of displacement from the initial line and the roughly estimated intensities of different components at the maximum electric field applied ($E_{max.}$), are tabulated below.

TABLE II.

λ : 4144

$E_{max.} = 60000$ volt/cm.

p-component.

	v_3	v_2	v_1	r_1	r_2
$\delta\lambda$ in Å.U.	−17·5	−7·0	−0·8	5·0	15·4
Intensity	2	4	10	7	4

s-component.

	v_3	v_2	v_1	r_1	r_2
$\delta\lambda$ in Å.U.	−14·0	−5·4	−1·2	5·1	13·4
Intensity	2	8	6	10	4

Thus we have 5 p- and 5 s-components, while Brunetti gives 6 components of which 3 are non-polarised. Stark states that there are at least 4 p- and 4 s-components for this line.

As shown in Pl. I, Fig. 1, the outermost component on the violet side is, so to speak, *isolated* from the initial line. The occurrence of these isolated components has already been noticed in the former paper for the two preceding members of this series (Parhelium I. N. S.), namely λ4922 and λ4388. As will be shown later, this remarkable phenomenon may be regarded as a characteristic feature of the diffuse series lines of both helium and parhelium. The appearance of the isolated component is best shown in Pl. III, Fig. 7 for the line λ4388.

(2) λ : 4026. (Pl. I, Fig. 2).

This line is a member of a doublet series; and according to

Runge and Paschen, we have 4026.512 (intensity 1) and 4026.342 (intensity 5).

TABLE III.

$\lambda : 4026$

$E_{max.} = 57000$ volt/cm.

p-component.

	v_3	v_2	v_1	r_1	r_2
$\delta\lambda$ in Å.U.	−10·6	−7·6	−1·7	5·6	7·4
Intensity	3	6	10	8	2

s-component.

	v_3	v_2	v_1	r_1	r_2
$\delta\lambda$ in Å.U.	−8·3	−6·4	−1·2	5·6	8·4
Intensity	3	6	10	8	2

For this line Brunetti gives 3 components, all being non-polarised. Stark, however, gives 3 p- and 3 s-component, of which only the central component shows the same amount of displacement. In Stark's monograph[1], it is stated that Koch observed 4 p- and 6 s-components.

In our study, there are 5 p- and 5 s-components, in each of which the two violet components are isolated, and start from a point lying at about E = 5000 volt/cm., and $\Delta\lambda = -1.1$ Å.U. Here it must be remarked, however, that, for the diffuse series lines of helium, the appearance of the isolated component is not so markedly shown as in the case of parhelium.

In the former experiment, it was noted that the central s-component of the line λ 4388 was apparently displaced about 0.3 Å.U. toward the violet at E = 20000 volt/cm. A quite similar behaviour of the central component was observed for the line under consideration. The reproduction (Pl. IV, Fig. 8) will show the discontinuity in the central line. A more complete study will be necessary to determine the transition state of this central component. As a possible cause of this feature, we may remark that the presence of the neighbouring line λ 4024.1 (Parhelium II. N. S. 7) may affect the appearance of the line under consideration.

[1] Stark, „ Electrische Spectralanalyse chemischer Atome" Leipzig. S. Hirzel, (1914).

Here it is to be remarked that in the measurement of the lines, as shown in Figs. 8 and 9, the correction due to the curvature of the lines was always taken into account.

(3) λ : 4009 (Pl. I, Fig. 3).

So far as we are aware, the electric effect on this line has not hitherto been observed. Owing to its feeble intensity, there was much difficulty in measuring the amounts of separation.

TABLE IV.

λ : 4009

$E_{max.} = 31500$ volt/cm.

p-component.

	v_2	v_1	r_1	r_2
$\delta\lambda$ in Å.U.	−11·2	−2·5	6·0	10·3
Intensity	5	2	10	3

s-component.

	v_3	v_2	v_1	r_1	r_2
$\delta\lambda$ in Å.U.	−10·3	−4·0	−0·6	5·2	9·0
Intensity	5	3	2	10	3

Although in the reproduction (Pl. III, Fig. 6) the line appears only very faintly, yet under the microscope we could observe an isolated component on the violet side for both of the p- and s-component.

(4) λ : 3820 (Pl. I, Fig. 4).

For this line we have only the data given by Stark and Kirschbaum[1] who observed 4 p- and 4 s-components. As shown in Fig. 4, our results agree quite well with those of Stark.

[1] Stark and Kirschbaum, loc. cit.

TABLE V.

λ : 3820

$E_{max.} = 60000$ volt/cm.

p-component.

	v_2	v_1	r_1	r_2
$\delta\lambda$ in Å.U.	−11·8	−4·3	4·2	10·2
Intensity	2	8	10	4

s-component.

	v_2	v_1	r_1	r_2
$\delta\lambda$ in Å.U.	−10·8	−3·0	2·6	10·5
Intensity	2	8	10	4

In Fig. 4 it will be seen that the outermost violet component is displaced to an extent greater than the corresponding red component. It is, we think, very probable that we have here also an isolated component, but its starting point is too close to the initial line to be seen separately. The next member λ 3705, observed by Stark and Kirschbaum, was too faint on our photographs.

(5) λ : 4169, 3965 (Pl IV, Fig. 9), 3868, 3614. 3448, 2945 (Pl. IV, Fig. 10).

All these lines are only displaced either toward the red or toward the violet in the electric field.

The results of our measurement are tabulated below.

TABLE VI.

λ in Å.U.	E in 10^4 volt/cm.	δλ in Å.U.		Remark
		p-comp	s-comp.	
4169	1·60	+0·9	+1·0	Stark gives $\delta\lambda_p$ ... +1·78, $\delta\lambda_s$ ... +1·60 at E=2.85
	2·30	+1·6	+1·5	
	3·20	+1·8	+1·7	
	5·70	+3·6	+3·6	
3965	1·60	−0·6	−0·4	Stark gives $\delta\lambda_p$ ... −0·40, $\delta\lambda_s$ ... −0·31 at E=2.85
	2·25	−0·8	−0·5	
	3·15	−1·3	−0·8	
	5·75	−2·0	−2·0	
3868	3·90	+0·3	+0·4	
	5·00	+0·5	+0·5	
	6·00	+0·6	+0·6	
3614	3·55	−2·6	−3·2	Stark gives $\delta\lambda_p$ ... +0·67, −2·31; $\delta\lambda_s$ ... +0·66, −1·82 at E=2·85
	5·00	−4·4	−4·2	
	6·00	−6·6	−4·4	
3448	2·00	−3·6	−3·0	
	3·85	−5·6	−4·4	
	5·70	−6·4	−7·6	
2945	2·00	+0·5	+0·5	
	3·30	+1·0	+0·9	
	5·70	+1·3	+1·5	

(6) λ : 4388 (Pl. I, Fig. 5).

This line has already been studied in the experiment by one of the present writers with Mr. Yoshida[1]. Here we give only the results of measurement on the photograph obtained in the present experiment which showed a greater number of components for this line.

1 T. Takamine and U. Yoshida, Mem. Coll. of Sci. Kyoto, 2, 325 (1917).

TABLE VII.

$\lambda : 4388$

$E_{max.} = 32000$ volt/cm.

p-component.

	v_3	v_2	v_1	r_1	r_2	r_3
$\delta\lambda$ in Å.U.	−10·2	−8·4	−4·4	0·8	5·3	7·8
Intensity	3	8	4	10	8	2

s-component.

	v_4	v_3	v_2	v_1	r_1	r_2	r_3
$\delta\lambda$ in Å.U.	−9·7	−8·2	−4·4	−0·4	4·0	5·7	8·6
Intensity	1	3	5	10	5	5	2

(7) $\lambda : 3830$

As stated above, the position of this line was calculated by Koch, using Ritz's formula. In our photograph we observed that both the p- and s-components of this line are displaced about 0.5 Å.U. toward the red at $E = 3.15 \times 10^4$ volt/cm.

§ 4.

In order to get a glance at the modes of separation of all the helium and parhelium lines hitherto investigated, diagrams were drawn as shown in Pl. II.

In the column giving wave-lengths in Å.U., the lines marked by asterisks were measured in the former experiment by one of the present writers with Mr. Yoshida[1], and those in rectangles are perhaps observed for the first time.

On examining the diagrams given in Pl. II., we notice the following facts :—

1). There are three different types of electric effect on helium lines, namely

a. Symmetrical decomposition, as shown by the line λ 4686 Å.U.

b. Non-symmetrical decomposition, as shown by the lines belonging to the diffuse series of helium and parhelium.

1 T. Takamine and U. Yoshida, Mem. Coll. of Sci., Kyoto, **2**, 325 (1917).

c. One-sided displacement, as shown by the lines belonging to the principal and sharp series of helium and parhelium.

2). Of the lines showing the one-sided displacement, only those belonging to the principal series of parhelium are displaced toward the violet side.

3). The lines belonging to the diffuse series are usually accompanied by an isolated component on the violet side.

4). The starting point of the isolated component, which is marked by a small circle in the figure, approaches more and more to the initial line as the term number of the line in the series increases.

If we denote the distance of the starting point of the isolated component from the initial line by $\Delta\lambda$, we have the data as shown in Table VIII.

TABLE VIII.

Diffuse Series of Helium				
Term number	λ in Å.U.	Δλ in Å.U.		
		p-comp.	s-comp.	Mean
4	4472	−1·6	−1·6	−1·6
5	4026	−1·2	−1·0	−1·1

Diffuse Series of Parhelium				
Term number	λ in Å.U.	Δλ in Å.U.		
		p-comp.	s-comp.	Mean
4	4922	−13·0	−13·2	−13·1
5	4388	− 4·6	− 5·2	− 4·9
6	4144	− 3·2	− 2·8	− 3·0
7	4009	− 2·0	− 2·0	− 2·0

So far as our experiment is concerned, the field strength at which the isolated component first appears is of the order of several thousands volt per cm.

5). Stark remarks that for the lines belonging to the sharp series, helium lines are less affected than those of parhelium. In the present experiment, the same feature was observed also for the lines of principal series and diffuse series.

6). Former investigation of Stark and Kirschbaum[1], and also that of Lüssem[2], have shown that, in the electric effect on helium and lithium lines, the amount of displacement of the diffuse series lines increases as the term number increases. In the present experiment,

1 Stark and Kirschbaum, loc. cit.

2 Lüssem, Ann. d. Phys., **49**, 865 (1916).

this relation was found to hold good even for the higher members of these series in the helium spectrum.

7). For the lines of helium and lithium, Stark remarked that the decomposition of the p-component is generally a little greater than that of the s-component. This was found to be true for most lines examined in the present experiment.

It may be remarked here that, as the amount of displacement differ only slightly for p- and s-component, it is very likely that they might be mistaken for "non-polarised," when examined with a spectroscope having a small dispersion.

Summary.

1. Adopting Lo Surdo's method, the effect of an electric field on the ultra-violet spectrum lines of helium has been investigated.

In addition to the 9 lines λ 5048, 5016, 4922, 4686, 4519, 4472, 4438, 4388 and 4121 examined in the previous experiment, the electric effect on the following 11 lines has been observed in the fields lying between 3000 to 70000 volt/cm.

λ : 4169, 4144, 4026, 4009, 3965, 3868, 3830, 3820, 3614, 3448, 2945.

The results have been compared with those of Stark, Brunetti and Koch.

3. It has been found that there are three different ways in which helium lines are affected by an electric field, namely :—

(i). Symmetrical decomposition (λ 4686 line).

(ii). Non-symmetrical decomposition (Diffuse series lines of helium and parhelium.)

(iii). One-sided displacement (Principal series lines and sharp series lines of helium and parhelium). Of (iii), only the lines belonging to the principal series of parhelium are displaced toward the violet side, while the other three series lines are all displaced toward the red side.

4. Diffuse series lines are usually accompanied by an isolated component on the violet side, whose starting point approaches nearer and nearer to the initial line as the term number increases.

5. The line λ 3830, whose position was calculated by Koch, but not observed by him, appeared in some of the photographs taken in the present experiment.

Beside the helium lines mentioned above, two lines at λ 2804 and λ 2482 Å.U., probably due to mercury, were found to be displaced slightly toward the red in the electric field.

In conclusion the writers wish to express their hearty thanks to Professor T. Mizuno for his interest in the work.

Fig. 1. λ : 4144

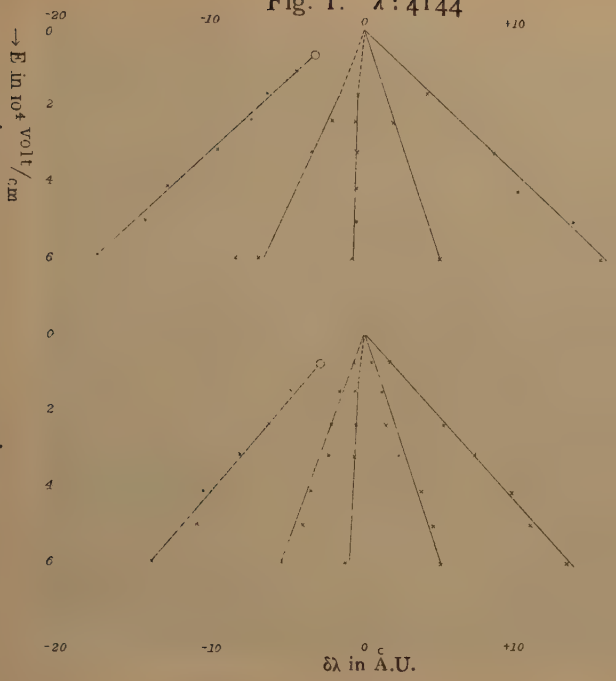


Fig. 2. λ : 4026

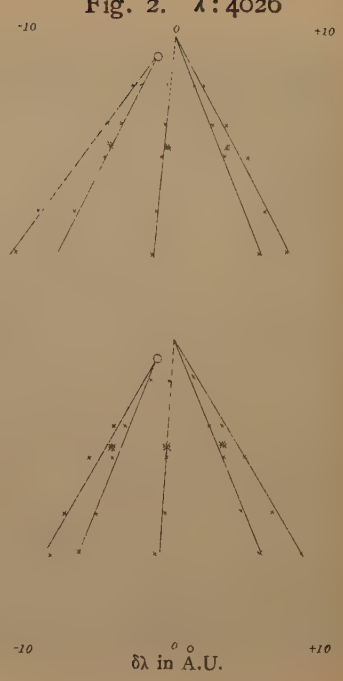


Fig. 3. λ : 4009

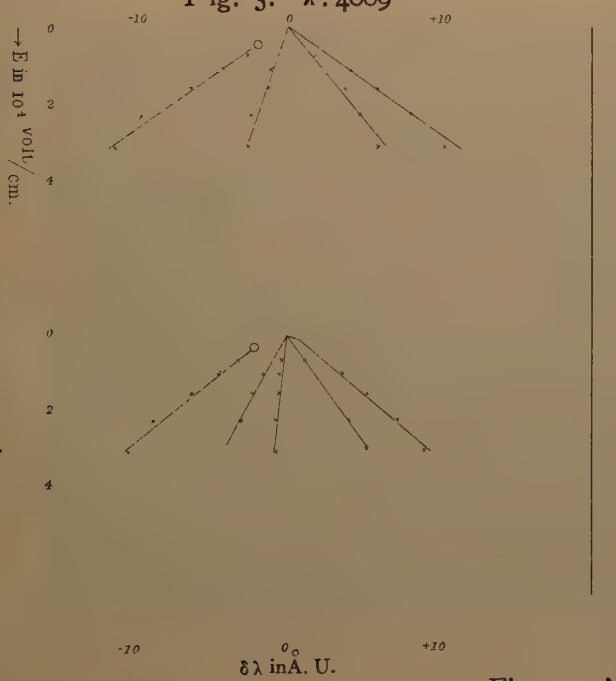


Fig. 4. λ : 3820

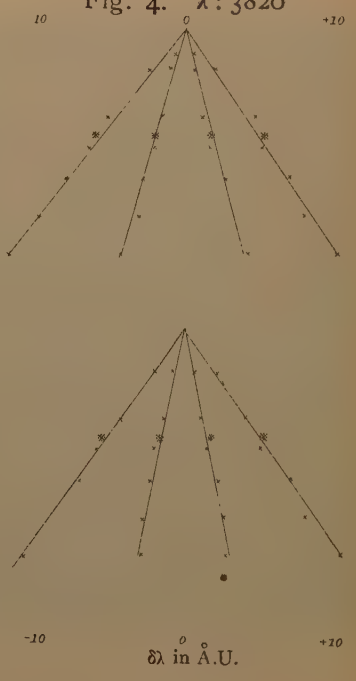
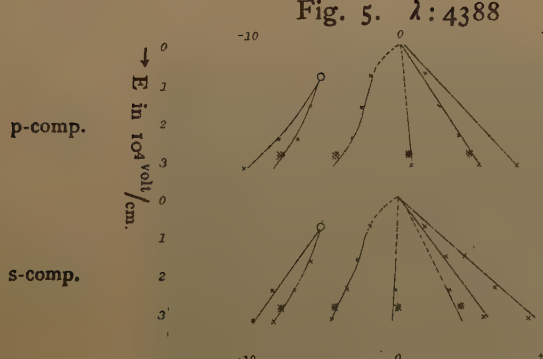
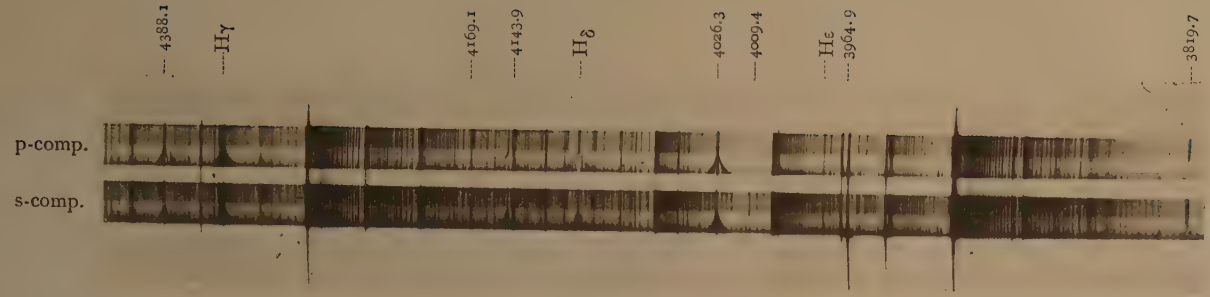


Fig. 5. λ : 4388



*.....Observed by Stark and Kirschbaum.

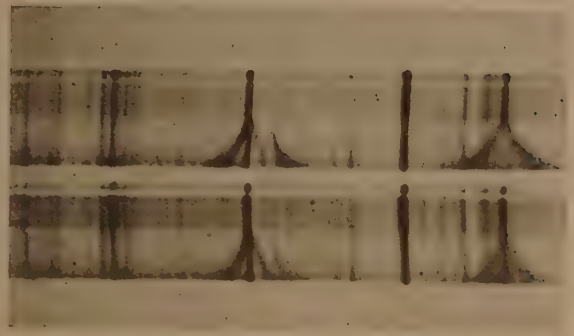
Fig. 6.



Magnification : 6

$E_{max.}$: 3.15×10^4 volt/cm
Exp. : 1h 40m
Spectrograph : 2 prism.

Fig. 7.

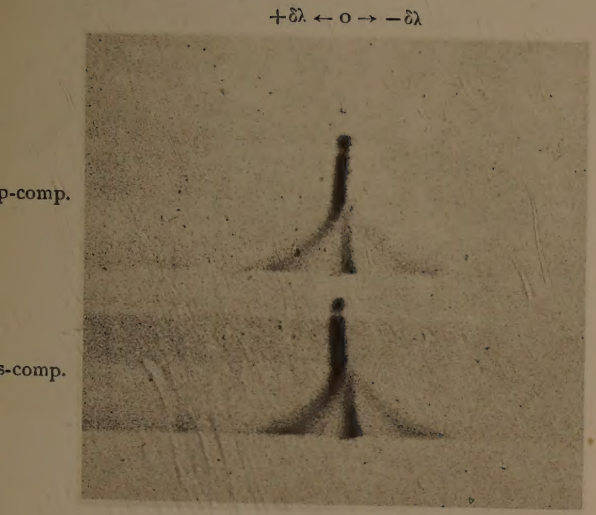


Magnification : 14

$E_{max.}$: 3.15×10^4 volt/cm.
Exp. : 1h 40m
Spectrograph : 4 prism.

Fig. 8.

λ : 4026

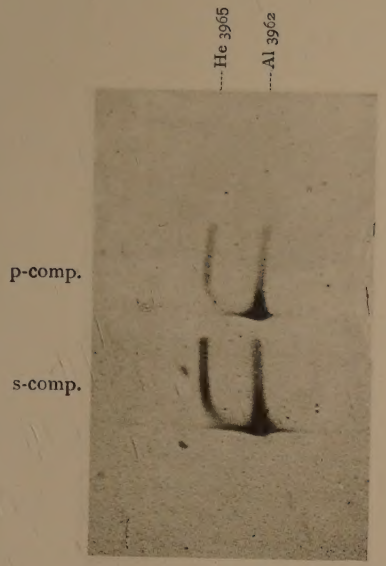


Magnification : 18

$E_{max.}$: 3.15×10^4 volt/cm.
Exp. : 1h 40m
Spectrograph : 4 prism.

Fig. 9.

λ : 3965

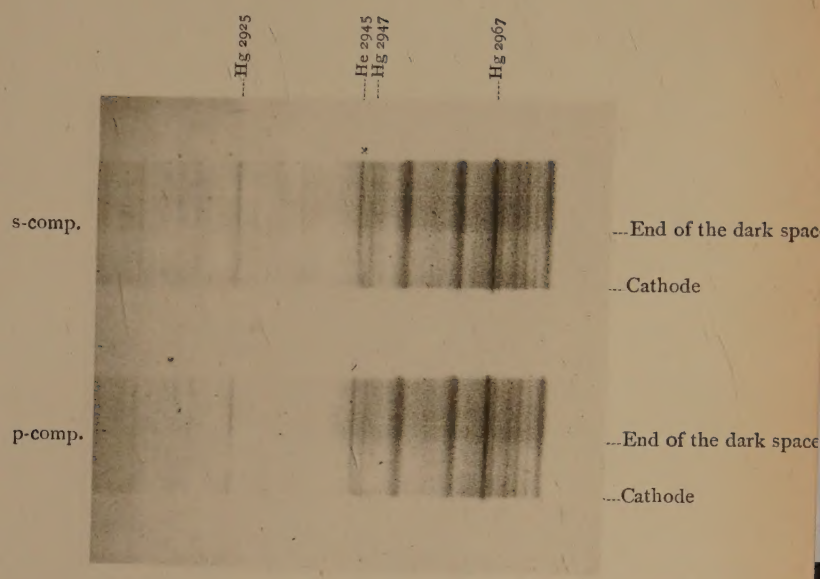


Magnification : 13

$E_{max.}$: 5.7×10^4 volt/cm.
Exp. : 1h 40m
Spectrograph : 4 prism.

Fig. 10.

λ : 2945



Magnification : 12

$E_{max.}$: 6.0×10^4 volt/cm.
Exp. : 1h 30m
Quartz spectrograph.

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